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Sampling uncertainty associated with western Mediterranean pelagic fish abundance estimates derived from acoustic data

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Abstract

Acoustic surveys are used worldwide for the assessment of pelagic fish stocks. In the Spanish Mediterranean area acoustic surveys are performed annually in late autumn and cover the entire continental shelf between 30 and 200 m depth. This survey was initiated to obtain estimates of anchovy recruitment (*Engraulis encrasicolus*), but additionally provide a general overview of the whole pelagic fish community in the study area during the time of the year it is performed. Our study area has a diverse assemblage of small and medium-sized pelagic fish (up to nine species) and thus we rely on the proportion of species obtained in middle-water pelagic fishing trawls to attribute the amount of echo corresponding to every single species and estimate their abundance. Although uncertainties may arise from many different sources (e.g. transducer motion, target strength, migration) we focus our study on the estimation of overall sampling uncertainty, one of the main contributors to random error. We apply geostatistical techniques to deal with spatial correlation and discuss benefits and pitfalls in their application. Although transitive geostatistics have seldom been used, most probably due to their inability to produce spatial maps of abundance and variance estimations, they constitute a powerful tool to routinely estimate sampling variance and its variation in time in a multi-specific context. They may also help to assess the effects of varying sampling intensity and could potentially be useful to detect possible processing errors, for example, in echogram scrutinizing. These techniques may therefore potentially help improve both the precision and the accuracy of acoustic data.

Keywords: Sampling uncertainty, geostatistics, acoustic surveys, pelagic fish, Mediterranean Sea

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Introduction

Sardine (*Sardina plichardus*) and anchovy (*Engraulis encrasicolus*) are two small pelagic fish species which play an important role in Western Mediterranean fisheries in terms of landed biomass and commercial interest (Lleonart and Maynou, 2003). They represented between 65 and 92 % of the biomass in the Balearic Sea coastal pelagic fish community during the period 2003 to 2006 (unpublished data, IEO). Small pelagic fishes are also clue links for energy transfer between the lower and the upper levels of the trophic chain. Their sensitivity to environmental variability and changes (Cole and McGlade, 1998, Lloret *et al*., 2004) may trigger abrupt increases and decreases of their populations which may affect both the fisheries that sustain and the structure and functioning of the ecosystem (Cury *et al.,* 2000, Shannon *et al*., 2000, Daskalov, 2002). Anchovy and sardine abundance show a declining trend since 1992 in the continental shelf of the Balearic Sea (Giráldez *et al.,* 2006a,b). Moreover, there is an increasing concern about the possible over-exploitation of anchovy's recruitment since an important fraction of the fishing effort relies on immature fishes (Pertierra and Lleonart, 1996).

Since the '90s, an acoustic survey is annually performed to estimate the abundance and biomass of sardine and anchovy along the entire Spanish Mediterranean continental shelf (ECOMED surveys). The survey is carried out in late autumn and its main aim is to estimate anchovy's recruitment as well as the abundance and biomass of sardine and of the other accompanying pelagic fish species. The accompanying species are Mediterranean horse mackerel (*Trachurus mediterraneus*), round sardinella (*Sardinella aurita*), bogue (*Boops boops*), Atlantic horse mackerel (*Trachurus trachurus*), blue jack mackerel (*Trachurus picturatus*), chub mackerel (*Scomber colias*) and atlantic mackerel (*Scomber scombrus*). However, the precision and accuracy of the estimates remain unknown.

There is an international increasing interest in routinely incorporation error estimation to the abundance and biomass estimates as a way of assessing their quality. This may be crucial in order to develop and implement sustainable management policies for the main pelagic fisheries. Nevertheless, this is not an easy task as there is a variety of sources of uncertainty in echointegration acoustic surveys like species migration, bubbles of air in the surface of the water column, movement of the research vessel, hidrographic conditions or vessel avoidance (see Simmonds & MacLennan 2005 for a complete review).

The main objective of the present study is to estimate the precision of anchovy and sardine abundance estimates derived from winter Spanish acoustic surveys for the period 2003 to 2006. We focus on the estimation of the overall sampling uncertainty as it is thought to be one of the main contributors to random error in acoustic surveys (ICES 1998). Classical statistics do not allow an unbiased estimation of variance of acoustic data as samples are not randomly distributed across the study area and show spatial autocorrelation. Geostatistics take the spatial autocorrelation into account and provide an unbiased estimation of the sampling variance (Matheron, 1965). In particular, transitive geostatistics in 1D were firstly applied to fisheries acoustics and considered suitable for monitoring total quantities of stock in regularly spaced sampling schemes (Petitgas, 1993), which are generally used in acoustic surveys.

Materials and methods

Study area

The study area comprises the continental shelf of the Spanish Mediterranean Sea from the Spanish-French border till the wetland Albufera de Valencia (Figure 1) with a total planar area of 4 200 nm^2 (about 14 406 km^2). Morphological features of the continental shelf divide the study area into two subareas. The most northern part, Roses-Barcelona (RB), extends from the Spanish-French border till Cape Salou and is characterised by a narrow shelf indented by submarine canyons that cut across a planar area of 1 200 nm^2. The southern part, Delta del Ebro (DE), which extends from Cape Salou to Albufera de Valencia, have a wide continental shelf shaped by the Ebro river, which is the second most important contributing river in western Mediterranean Sea. The total planar area of Delta del Ebro subarea is 3 000 nm^2.

Data collection

Acoustic data was collected on board the R/V "Cornide de Saavedra" during the end of November and beginning of December of 2003, 2004, 2005 and 2006 in the context of annual surveys of pelagic fish stock assessment in the Spanish Mediterranean Sea (ECOMED). Data was continuously recorded at constant speed of 10 knots along parallel equidistant transects placed perpendicular to bathymetry and using a scientific split-beam echosounder, SIMRAD EK500 or EK60, working at 38 kHz. Acoustic sampling was performed from sunrise to sunset covering the entire continental shelf between 30 and 200 m depth. The echosounder was calibrated prior to each survey following standard techniques (Foote 1987). Inter-transect distance was established to 4 nm in Roses-Barcelona subarea and 8 nm in Delta del Ebro subarea according to the width of the continental shelf (Figure 1). Transects were numbered from 1 to 48 from North to South (Figure 1), 33 transects belonging to Roses-Barcelona subarea (from number 1 to number 33) and the 15 left belonging to Delta del Ebro subarea (from number 34 to number 48).

Mid-water pelagic fishing trawls were performed after sunset and directed to obtain the species proportions present in the area with a pelagic trawl net of 12 m vertical opening. The trawls were performed at 3.5 – 4.5 knots and approximately 1 hour length. The amount of pelagic fishing trawls were between 26 and 32, depending on the year.

Data processing

Acoustic data was integrated at every Elementary Distance Sampling Unit (EDSU) which was set to 1 nautical mile using the Sonardata Echoview software. The amount of echointegrated EDSUs was between 670 and 679 in the entire study area, depending on the year. The result of the echointegration, NASC (Nautical Area Scattering Coefficient) or s_A (m^2 mn^{-2}), was divided into species using the composition of the trawl catches and following Nakken and Domasnes method for multiple species (Nakken and Domasnes, 1975). Anchovy NASC and sardine NASC were translated into number of fishes using a b_{20} value of -72.6 dB (Degnbol *et al.*, 1985) and mean size per species in each study subarea (Table 1).

Estimation of sampling precision

Anchovy and sardine abundance data was reduced from 2D to 1D by summing up the abundance in each transect for each of the four years in the study. The abundance, Q, is then estimated by integration of transect cumulates, $q(x)$:

$$Q = \int_{-\infty}^{+\infty} q(x)dx$$

Assuming that the variable equals to zero outside the study area the abundance was approximated by a discrete sum:

$$Q^* = a\sum_{k=1}^{n} q(x_0 + ka)$$

where a is the inter-transect distance and x_0 is the random coordinate of the first transect.

Sampling variance (σ^2_{geo}) was estimated as the difference between the experimental transitive covariogram, $g^*(ka)$, and a theoretical model (or combination of nested models) $g(h)$, to which the data was adjusted according to the formula:

$$\sigma^2_{geo} = a\sum_{k=-\infty}^{+\infty} g^*(ka) - \int_{-\infty}^{+\infty} g(h)dh$$

The experimental transitive covariogram was computed using the formula:

$$g^*(ka) = a\sum_{i}^{+\infty} q(x_i)\ q(x_i + ka),$$

where a is the inter-transect distance and q(x) represents the cumulated abundance by transect (Petitgas and Prampart, 1993).

For the structural analysis, we applied spherical and exponential theoretical models of the form:

- Spherical: $$g(h) = \begin{cases} C\left(1 - 1.5\dfrac{h}{r} + 0.5\dfrac{h^3}{r^3}\right) & if\ h \le r \\ 0 & if\ h > r \end{cases}$$

- Exponential: $$g(h) = C\ \exp\left(\frac{-abs(h)}{r}\right) \quad \forall h$$

In these models r is the range at which the sill (or saturation of variance) is reached, C is the sill (or value of the variance where it stabilises) and h is the distance in absolute value at which the sill is reached. The models fitted in our study did not need the addition of a nugget effect and were constructed by nesting two or three simple models.

The covariograms were computed and fitted to a model by eye using the software EVA2 (Petitgas and Lafont, 1997). The goodness of fit (gof) of the models was computed using an Excel worksheet following Rivoirard *et al.*, (2000).

$$gof = \frac{\sum_{h}[g(h) - g*(ka)]^2}{\sum_{h}[g*(ka)]^2}$$

The closer the goodness of fit to 0 the better the fitting. Models with gof ≥ 0.1 were rejected and an alternative model was seek till a model with gof < 0.1 was found.

An unbiased estimator of the coefficient of variation of the abundance estimation (CV_Q) is provided by the formula:

$$CV_Q = \frac{\sqrt{\sigma^2_{geo}}}{Q*}$$

Lower CV_Q values indicate higher precision of the abundance estimation. Moreover, while variance depends on abundance, sampling intensity and homogeneity of the spatial distribution of the variable under study CV_Q only depends on sampling intensity and on the spatial distribution.

The analysis of the effects of varying sampling intensity was performed, first, by removing transects with odd numbers and, second, by removing transects with even numbers to achieve an inter-transect distance of 8 nm in Roses-Barcelona and 16 nm in Delta del Ebro, which doubles the original sampling intensity.

Results

Roses-Barcelona subarea

Cumulated abundance per transect show that anchovy tends to gather together in the most northern part of the Roses-Barcelona area and, concretely, in the 8 most northern transects (Figure 2). The maximum cumulates for anchovy are found year after year in the Gulf of Roses area (transects 5 and 6). In the case of sardine, the higher proportion of the abundance is also found in the most northern part but only in two of the four years (2004 and 2005) while in the other two years the bulk of the sardine abundance was more southerly detected (Figure 2).

The structural analyses of the covariograms showed that in the models of Roses-Barcelona subarea the short range explain most of the variance both for anchovy and for sardine, ranging from 97.3% to 99.6% for the former and from 97.7 to 99.7 % for the latter (Table 2). The experimental transitive covariograms and the fitted models are shown in Figure 3.

The estimated abundance of anchovy and sardine is rather similar across the studied period, with the exception of the year 2003 (Table 3). The abundance of both species seems to be declining although in the case of anchovy the drop is considerably more intense as anchovy descended from 1 811 millions of individuals in 2003 to 268 millions of individuals in 2006 while for sardine the descend was from 426 to 192 millions of individuals.

The geostatistical variance estimation for anchovy ranges from 0.27 10^{15} to 54.15 10^{15} while for sardine it ranges from 0.42 10^{15} to 1.85 10^{15} (Table 3). The coefficient of variation of the abundance estimation varies from 6.48 to 14.54% for anchovy and from 6.98 to 16.92% for sardine. For the first two years sardine abundance estimation is more precise than anchovy abundance estimation while for 2005 and 2006 anchovy abundance estimation is more precise than sardine's (Table 3). Moreover, as the CV_Q does not depend on abundance and as within a subarea the sampling intensity is constant, variations of CV_Q between years and between species imply variations in the homogeneity of the spatial distribution. Thus, an analysis of the CV_Q suggests that 1D spatial distribution of anchovy is patchier than the spatial distribution of sardine in 2003 and 2004 while in 2005 and 2006 its spatial distribution is more homogeneous than sardine spatial distribution.

Delta del Ebro subarea

In this subarea an important amount of anchovy abundance concentrates in the three most northern transects (transects 34 to 36) as it is seen in the cumulated abundance by transect (Figure 4). These three transects are found right in the north of the Delta del Ebro river mouth. In the year 2006 anchovy abundance is southwardly displaced and coincides with the bulk of sardine abundance, which is located in transects number 37 to number 39.

The structural analyses show that the short range explains a great amount of the variance for both species, ranging between 84.2 and 99.4 % for anchovy and between 66.5 and 79.7% for sardine (Table 4). The experimental transitive covariograms and the fitted models are shown in Figure 5.

Anchovy and sardine abundance show a declining trend in the studied period, like in Roses-Barcelona subarea, but in this case the sardine fell more intensively than anchovy as it dropped from 3 476 to 1 018 millions of individuals while anchovy descended from 1 675 to 1 188 millions of individuals (Table 5).

Variance of the total abundance estimation in Delta del Ebro subarea varies between 0.92 10^{15} and 46.98 10^{15} for anchovy and between 4.72 10^{15} to 46.6 10^{15} for sardine (Table 5). In this subarea, the coefficient of variation of the abundance estimation for sardine is extraordinarily stable for sardine ranging from 6.22 and 6.75 %. In the case of anchovy it could also be considered rather stable but in 2006 the CV_Q is astonishingly high (18.5%) (Table 5). Contrary to what was observed in Roses-Barcelona subarea, the precision of anchovy abundance is higher than the precision of sardine abundance for the first two years, while in 2005 and 2006 the precision is higher for the sardine estimation.

Variation of the sampling intensity

Roses-Barcelona subarea (8 nm)

The structural analyses of the covariograms reveal that short ranges continue explaining most of the variance in Roses-Barcelona subarea in all the cases considered, both for the odd and even numbered transects (Table 6). The models fitted for the odd numbered transects are quite similar to those fitted in the original dataset, showing the same sill in the long range than the models fitted for the original dataset and a reduction of the sill in the short range, which was more intense in the case of anchovy (Table 6). Models computed with even numbered transects showed an increase of the sill in the short range component and a reduction of the sill in the long range compared to the original dataset (Table 6).

Anchovy abundance estimation increases when only the odd numbered transects are considered while it is reduced when only the even are included (Table 7). In the case of sardine, the higher abundance is obtained when even numbered transects are included while lower abundance is estimated when the odd are used (Table 7).

The variance and coefficient of variation increased in all of the cases but was slightly higher when using the odd numbered transects, in the case of anchovy, and when using the even numbered transects, in the case of sardine (Table 7).

Delta del Ebro subarea (16 nm)

The structural analyses of the covariograms reveal that, in general, short range continues explaining a greater part of the variance both for the odd and even numbered transects (Table 8). The models are very similar to those fitted for the original dataset. In the long range the sill is exactly the same than the sill found in the original dataset both for the odd and for the even transects while in the short range the sill is reduced in the even transects for the anchovy and in the odd transects model for sardine (Table 8).

Anchovy abundance estimation increases when only the odd numbered transects are considered while it is reduced when only the even are included (Table 9). In the case of sardine, the higher abundance is obtained when even numbered transects are included while lower abundance is estimated when the odd are used (Table 9).

The variance and coefficient of variation increased in all of the cases but was slightly higher when using the odd numbered transects, in the case of anchovy, and when using the even numbered transects, in the case of sardine (Table 9).

Discussion

The maximum cumulated abundance per transect for anchovy and sardine seem to show certain spatial segregation in a latitudinal direction especially clear in Roses-Barcelona subarea in the years 2003 and 2004 (Figure 2). Some studies have related spatial segregation between sardine and anchovy to an increase in biomass (Barange *et al.*, 2005) but this was not observed in the present study.

A clear overlap between the spatial distribution between anchovy and sardine in Delta del Ebro subarea in the year 2006, being the anchovy maximum abundance per transect clearly southwardly displaced in comparison with the preceding years. The precision of the anchovy abundance estimation is exceptionally low with a CV_Q of about 18%. These led to a revision of the echogram scrutinization by an expert and a possible overestimation of anchovy abundance was detected but it could not be proved since the detection was not during the cruise and confirmation trawls could not be performed.

The highest abundance of anchovy is located in the most northern part of the two subareas under study, with the exception of Delta del Ebro in the year 2006. These locations are the places in the study area with a higher enrichment produced by the influence of the two main rivers in Western Mediterranean, Rhône and Ebro (Arnau *et al*., 2004).

The precision of the abundance estimations is similar to the precision estimated by the same method in different areas and studies; a CV_Q of 12.5% was computed for Norwegian herring in an area with inter-transect distance of 4.54 nm (Petitgas, 1993) and between 4 and 15% for a mixture of pelagic fish in Senegal (Samb and Petitgas, 1997). In our study, abundance estimation is more precise in Delta del Ebro than in Roses-Barcelona subarea both for sardine and it is also more stable through the period under study.

The effects of reducing sampling intensity on the abundance estimation cannot be predicted as it will depend on where exactly transects are located. The structure of the covariogram will in most of the cases be similar and variance and coefficient of variation will be increased. In the Delta del Ebro subarea an inter-transect distance of 16 nm will bring similar CV_Q than the obtained in Roses-Barcelona subarea with the original dataset (4 nm inter-transect distance) which imply that anchovy and sardine abundance is much more homogeneously distributed in Delta del Ebro than in Roses-Barcelona. If CV_Q similar to Delta del Ebro was to be obtained in Roses-Barcelona the inter-transect distance would need to be reduced. It could be interesting in the case of anchovy as in some years the abundance of Roses-Barcelona is higher or similar to the abundance of Delta del Ebro but it will be useful to analyse a longer period to have significant conclusions.

Although transitive geostatistics in 1D do not provide 2D maps either for abundance nor for variance estimation it does provide unbiased estimation of the coefficient of variation of the overall abundance. Transitive geostatistics require less statistical assumptions than the more frequently used intrinsic geostatistics and may help to assess the effects of decreasing sampling intensity. It is true that some variance is not considered due to the dimensionality reduction but variance is expected to be much greater between transects than between samples along a transect. Transitive geostatistics could also reveal possible processing errors or weaknesses in the processing protocol helping improve the accuracy of the estimations.

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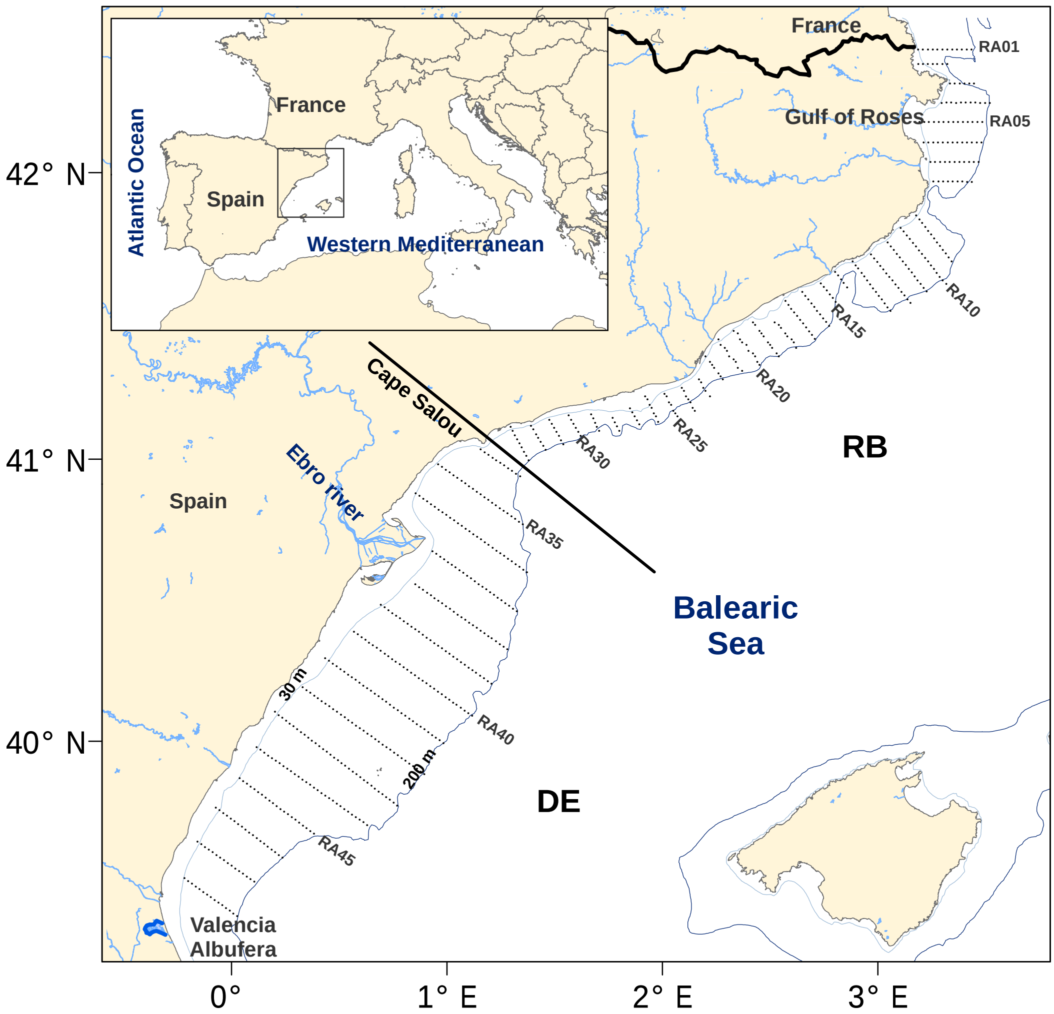

Figure 1. Study area, acoustic sampling scheme and identified subareas: Roses-Barcelona (RB) and Delta del Ebro (DE).

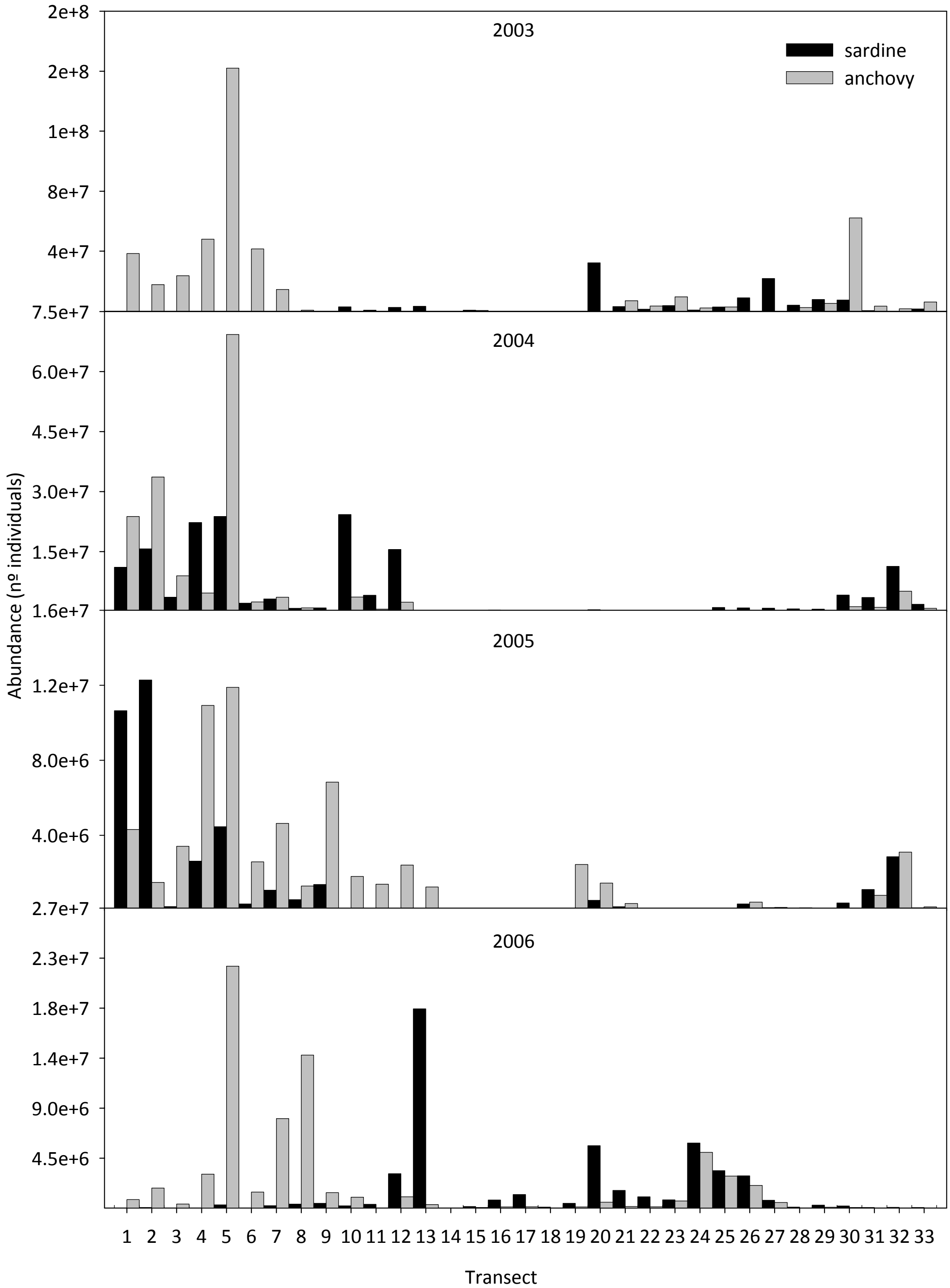

Figure 2. Anchovy and sardine cumulated abundance by transect in Roses-Barcelona subarea.

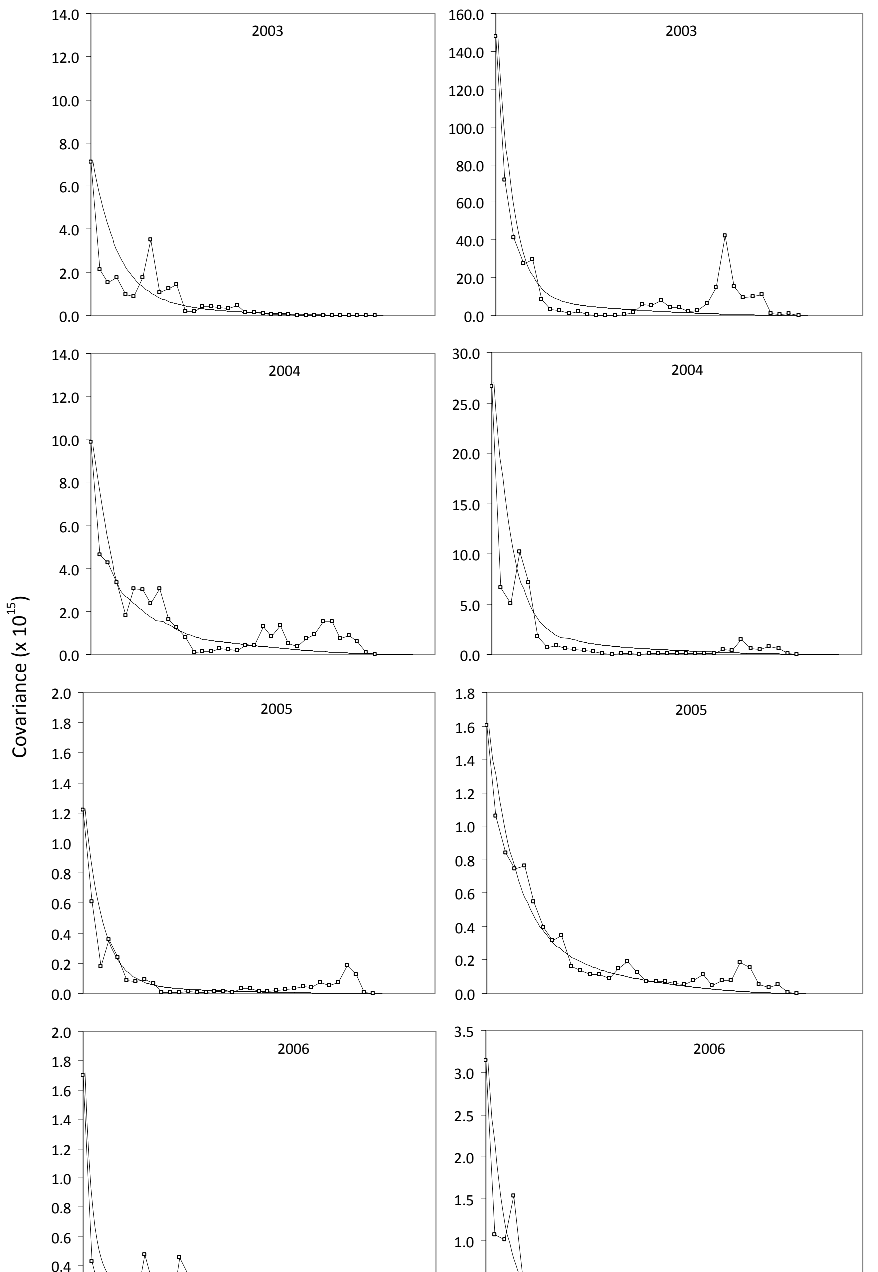

Figure 3. Experimental transitive covariograms (dotted line) and fitted models (solid line) for anchovy (left) and sardine (right) in Roses-Barcelona subarea. Note that the y-axis differ for the different plots.

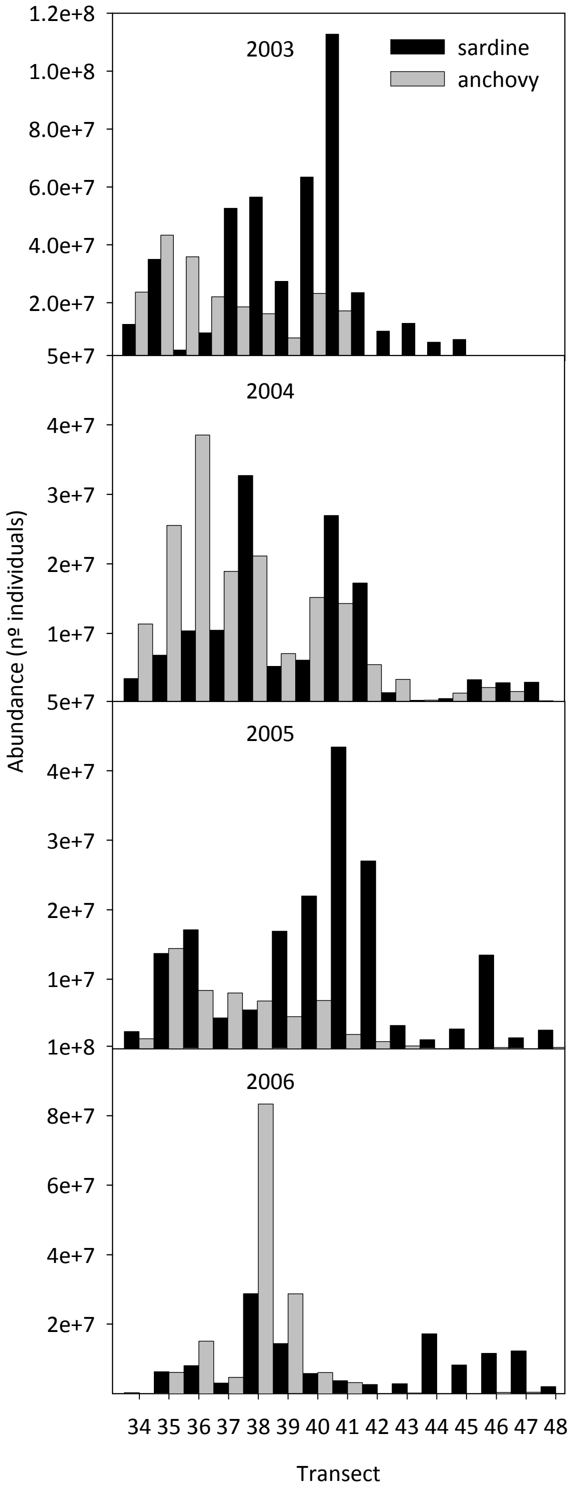

Figure 4. Anchovy and sardine cumulated abundance by transect in Delta del Ebro subarea.

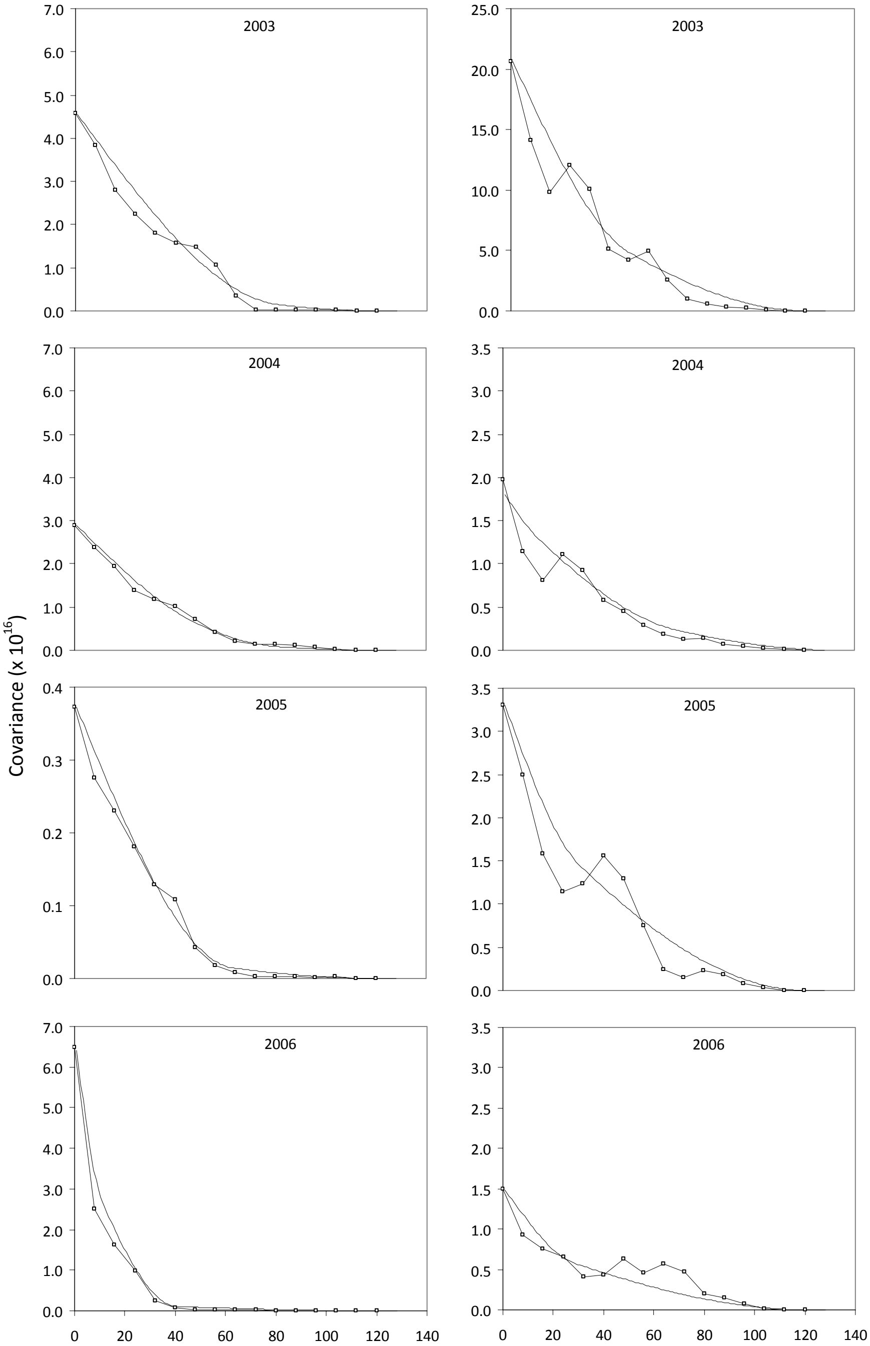

Figure 5.Experimental transitive covariograms (dotted line) and fitted models (solid line) for anchovy (left) and sardine (right) in Delta del Ebro subarea. Note that the y-axis differ for the different plots.

Table 1. Mean total length (cm) per species and study subarea in the pelagic fishing trawls.

Subarea	RB		DE	
Species	anchovy	sardine	anchovy	sardine
2003	10.3	11.1	10.5	12.0
2004	9.8	12.2	10.5	12.1
2005	10.7	12.4	12.3	13.1
2006	10.9	14.8	11.3	16.0

Table 2. Summary of the structural analysis in Roses-Barcelona subarea. M: family model; Sph: spherical model, Exp: exponential model; R: range (nm); S: sill; %Var: % of variance explained

	Anchovy				Sardine			
Year	M	R (nm)	S ($x10^{15}$)	% Var	M	R (nm)	S ($x10^{15}$)	% Var
2003	sph	132	8.00	0.4	sph	132	0.50	1.2
	exp	20	140.00	99.6	exp	36	6.60	98.8
2004	sph	132	1.50	0.5	sph	132	1.40	2.3
	exp	24	25.50	99.5	sph	50	2.80	12.1
					sph	14	5.50	85.6
2005	sph	132	0.24	2.7	sph	132	0.05	0.3
	exp	36	1.35	97.3	exp	20	1.18	99.7
2006	sph	132	0.26	1.2	sph	132	0.20	0.6
	exp	20	2.90	98.8	sph	60	0.14	0.9
					exp	10	1.38	98.5

Table 3. Estimated abundance (Q*), variance (σ^2_{geo}) and coefficient of variation (CV_Q) for sardine and anchovy abundance estimation in Roses-Barcelona subarea.

	Anchovy			Sardine		
Year	Q* ($x10^6$ individuals)	σ^2_{geo} ($x10^{15}$)	CV_Q (%)	Q* ($x10^6$ individuals)	σ^2_{geo} ($x10^{15}$)	CV_Q (%)
2003	1 811	54.15	12.85	426	1.31	8.50
2004	656	9.10	14.54	615	1.85	6.98
2005	255	0.27	6.48	160	0.42	12.83
2006	268	1.12	12.49	192	1.06	16.92

Table 4. Summary of the structural analysis in Delta del Ebro subarea. M: family model; Sph: spherical model, Exp: exponential model; R: range (nm); S: sill; %Var: % of variance explained

	Anchovy				Sardine			
Year	M	R (nm)	S ($x10^{15}$)	% Var	M	R (nm)	S ($x10^{15}$)	% Var
2003	sph	120	10.00	15.8	sph	120	110.00	31.4
	sph	80	35.50	84.2	sph	48	96.00	68.6
2004	sph	120	5.68	12.4	sph	120	8.00	20.3
	sph	80	17.80	58.4	sph	68	8.60	42.3
	sph	48	5.40	29.4	sph	14	0.14	37.4
2005	sph	120	0.50	7.3	sph	120	22.00	33.5
	sph	62	3.22	92.7	sph	80	1.00	2.3
					sph	30	10.00	64.2
2006	sph	120	2.00	0.7	sph	120	8.70	24.6
	sph	40	10.00	27	sph	28	6.20	75.4
	sph	10	22.00	72.4				

Table 5. Estimated abundance (Q*), geostatistical variance (σ^2_{geo}) and geostatistical coefficient of variation (CV_Q) for sardine and anchovy abundance estimation in Delta del Ebro subarea.

	Anchovy			Sardine		
Year	Q* ($x10^6$ individuals)	σ^2_{geo} ($x10^{15}$)	CV_Q (%)	Q* ($x10^6$ individuals)	σ^2_{geo} ($x10^{15}$)	CV_Q (%)
2003	1 675	8.43	5.48	3 476	46.67	6.22
2004	1 335	6.12	5.86	1 050	4.78	6.59
2005	437	0.92	6.94	1 422	8.75	6.57
2006	1 188	46.98	18.25	1 018	4.72	6.75

Table 6. Summary of the structural analysis in Roses-Barcelona subarea with increased sampling intensity. M: family model; Sph: spherical model, Exp: exponential model; R: range (nm); S: sill; %Var: % of variance explained; a: inter-transect distance

			Anchovy				Sardine			
Year	Included transects	a (nm)	M	r (nm)	S ($x10^{15}$)	% Var	M	r (nm)	S ($x10^{15}$)	% Var
2003	Odd	8	sph	136	8.00	0.2	sph	136	0.50	1.4
			exp	18	2.20	99.8	exp	30	4.00	98.6
2003	Even	8	sph	128	7.00	0.8	sph	128	1.50	1.9
			exp	16	58.00	99.2	sph	48	1.00	3.4
							sph	14	7.20	94.6

Table 7. Estimated abundance (Q*), geostatistical variance (σ^2_{geo}) and geostatistical coefficient of variation (CV_Q) for sardine and anchovy in the year 2003 with increased sampling intensity. a: intertransect-distance;

			Anchovy			Sardine		
Year	Included transects	a (nm)	Q* ($x10^6$ indiv.)	σ^2_{geo} ($x10^{15}$)	CV_Q (%)	Q* ($x10^6$ indiv.)	σ^2_{geo} ($x10^{15}$)	CV_Q (%)
2003	Odd	8	2 185	384.26	28.37	368	3.14	17.47
2003	Even	8	1 437	115.97	23.69	484	9.71	19.15

Table 8. Summary of the structural analysis in Delta del Ebro subarea with increased sampling intensity. M: family model; Sph: spherical model, Exp: exponential model; R: range (nm); S: sill; %Var: % of variance explained; a: inter-transect distance

			Anchovy				Sardine			
Year	Included transects	a (nm)	M	r (nm)	S ($x10^{15}$)	% Var	M	r (nm)	S ($x10^{15}$)	% Var
2003	Odd	16	sph	112	10.00	15.8	sph	112	110.00	60.8
			sph	80	38.00	84.2	sph	80	46.00	39.2
2003	Even	16	sph	128	10.00	17.2	sph	128	110.00	16.2
			sph	80	30.00	82.8	sph	40	160.00	83.8

Table 9. Estimated abundance (Q*), geostatistical variance (σ^2_{geo}) and geostatistical coefficient of variation (CV_{geo}) for sardine and anchovy in the year 2003 in Delta del Ebro subarea. a: intertransect-distance

			Anchovy			Sardine		
Year	Included transects	a (nm)	Q* ($x10^6$ indiv.)	σ^2_{geo} ($x10^{15}$)	CV_Q (%)	Q* ($x10^6$ indiv.)	σ^2_{geo} ($x10^{15}$)	CV_Q (%)
2003	Odd	16	1 692	36.11	11.23	3 326	93.94	9.21
2003	Even	16	1 659	29.00	10.26	3 625	308.56	15.32